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1.9 µm-FIBER-PUMPED Cr:ZnSe LASER

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14. ABSTRACT
We report on a Cr^{2+}:ZnSe face-cooled disk laser pumped by a 1.9 micron Tm fiber laser. Direct modulation of the fiber laser permitted operation of the Cr laser at repetition rates from true CW to 1 kHz, with slope efficiencies up to 28 percent and thresholds as low as 200 mW, performance comparable to the case of Q-switched pumping.

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1.9 μm-Fiber-Pumped Cr:ZnSe Laser

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Abstract: We report a Cr^{2+}:ZnSe face-cooled disk laser pumped by a 1.9 μm Tm fiber laser. Direct modulation of the fiber laser permitted operation of the Cr laser at repetition rates from true CW to 1 kHz, with slope efficiencies up to 28% and thresholds as low as 200 mW, performance comparable to the case of Q-switched pumping.

OCIS Codes: (140.5680) Rare earth and transition metal solid-state lasers; (140.3070) Infrared and far-infrared lasers

Introduction

The Cr^{2+}:ZnSe laser is a promising candidate for tunable mid-IR applications because of its broadband emission in the 2-3 μm region, and its relatively efficient operation at room temperature. In spite of its known thermal effects, multiwatt output has been obtained using thin disk [1] as well as end-pumped-rod [2] configurations, typically using Tm-doped crystal lasers as the pump source. Fiber lasers offer key advantages over crystal laser pump sources in terms of size, simplicity, beam quality, and now output power, and operation of a Cr laser pumped by a 1.57 μm Er fiber amplifier has been demonstrated, with CW output power up to 230 mW [3]. Recent advances in fiber laser technology have made available Tm fiber lasers whose output wavelength of 1.9 μm is close to the peak Cr^{2+} absorption, and whose true-CW output powers exceed 100 W. We report a Cr:ZnSe laser pumped by a 1.9 μm Tm fiber laser and operating entirely at room temperature, with performance comparable to that obtained using a Q-switched Tm:YLF (crystal) pump source.

Experiment

The pump source for these experiments was a linearly polarized Tm fiber laser built by IPG Photonics. It produced close to 40 W of true CW output with near-diffraction-limited beam quality at a wavelength of 1907 nm, and could be operated in pulsed mode at repetition rates up to 2 kHz by direct modulation of the drive current to the pump diodes. The Cr^{2+} gain medium was a thin (0.5 mm) ZnSe disk doped to approximately 2×10^{19} cm^{-3} Cr^{2+} concentration, AR coated on one face and HR coated on the other face for both pump and Cr^{2+} laser wavelengths. The HR coated face was affixed to a water-cooled heat sink using conductive silver epoxy. A 95% reflective outcoupler with 10-cm concave radius of curvature provided the best performance, placed at a distance of 8.5 cm from the surface of the Cr:ZnSe disk. A 50 cm focal length lens was positioned to focus the pump to an approximately 3 mm diameter spot on the crystal, a spot that was reimaged by multi-pass pump optics for a total of 16 passes through the crystal, which was calculated to proved upwards of 95% pump absorption. Figure 1 shows the experimental arrangement.

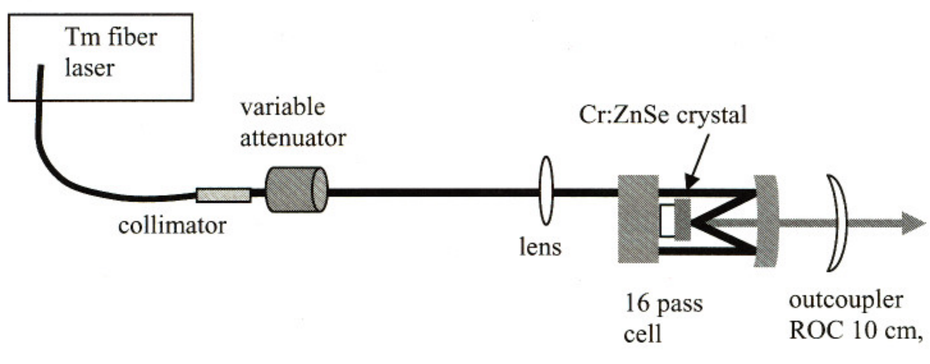


Fig. 1. Experimental setup.

Results

Threshold and slope efficiency based upon incident average pump power were measured with the pump laser modulated at 1 kHz for various duty cycles. The results are shown in Figure 2. Slope efficiency decreases and threshold increases at higher duty cycles as the thermal load on the crystal increases. At 10% duty cycle a slope efficiency of 28% was obtained, while an average output power of just over 1 W was obtained at a duty cycle of 25%. At 50% duty cycle, output power began rolling over as average pump power increased, again due to thermal effects. CW performance was considerably poorer, with a slope efficiency of 13%, threshold of 1.4 W, and highest output power of 335 mW. Pump power was limited to about 5 W in the CW case to avoid damage to the crystal. These results are comparable to those obtained previously with a 0.5 mm Cr:ZnSe disk in the 16-pass configuration using a Q-switched Tm:YLF laser for pumping [4].

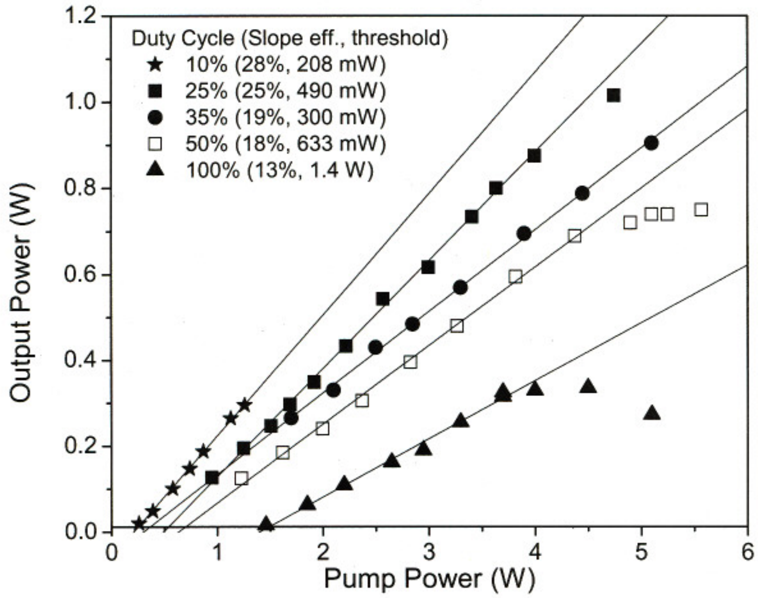
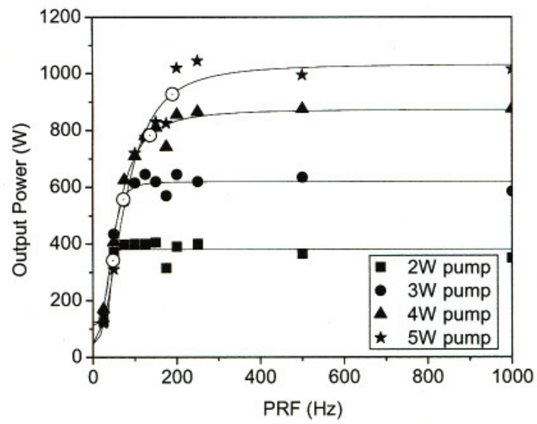


Fig. 2. Cr:ZnSe laser performance at various duty cycles.

The effects of thermal loading on beam quality were examined by looking at the M^2 parameter for several average pump power levels at a duty cycle of 25% and 1 kHz prf. M^2 was determined by fitting the gaussian beam waist equation to spot size measurements made along the beam path by manual knife edge scan. While M^2 generally increases with higher average pump power, the small number of data and the fluctuations in output power caused by increasing thermal effects at the higher pump power levels preclude more detailed conclusions. Direct observation of the output beam with an Electrophysics pyroelectric camera qualitatively confirmed the effects of thermal loading at 1 kHz prf, showing an increase in output beam size with both duty cycle and pump power, but fortuitously no evidence of beam breakup.

To gain additional perspective on thermal effects, average output power was measured as a function of repetition rate for various pump power levels at a fixed duty cycle of 25%. Since reducing the prf at a fixed duty cycle serves to elongate the pump pulses, as well as the "rest periods" between pulses, we were able to see essentially how long energy could be continuously deposited into the crystal before thermal loading became strong enough to affect output power. These results are presented in Figure 3. The left plot shows average output power as a function of prf, as directly measured. The circles correspond to the point on each trace at which the power has fallen to 90% of the maximum value. The right plot shows the pulse duration at which output power drops to 90% as a function of average pump power. Not surprisingly, as prf is reduced, output power falls off sooner at higher average pump powers; in other words, at lower pump powers one can pump the crystal longer before thermal loading affects output power.



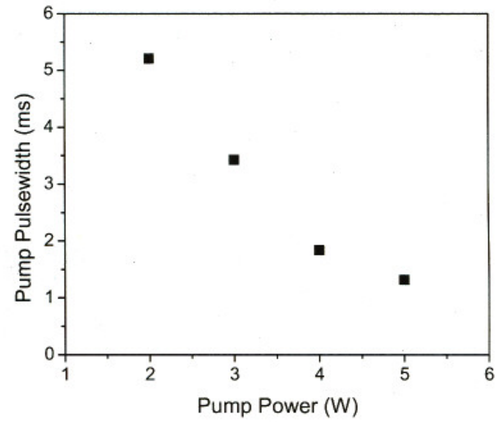


Fig. 3. Effects of thermal loading on output power. Output power as a function of prf (left) and average pump power at 25% duty cycle; and pulse duration at which output power drops to 90% of maximum.

Conclusion

We have demonstrated that a 1.9 μm fiber laser makes an effective and efficient pump source for Cr^{2+} lasers. Its operating wavelength lies close to the peak Cr^{2+} absorption to allow efficient pump absorption in lightly to moderately doped samples. The diode-pumped fiber architecture allows easy cooling and beam transport for an overall system that runs at room temperature and is compact, rugged, and streamlined. A main limitation of fiber lasers is the difficulty in obtaining Q-switched output at useful power levels, but pulsed Cr laser operation at kHz repetition rates and a spectrum of duty cycles can be obtained by simple modulation of the fiber pump laser, with performance comparable to that obtained using a Q-switched Tm crystal laser. Tm fiber lasers have clearly come of age as pump sources, and may often prove superior for applications requiring their unique advantages.

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